PRESIDENTIAL ADDRESS

A Global Perspective on Science and Technology

David Baltimore

THE UNITED STATES IS A HUGE OCEAN-FLANKED country that, since World War II, has led the world in the development of science and technology. But other countries are now catching up. The American Association for the Advancement of Science (AAAS) has been a support for the development of American science since the 19th century, but as the rest of the world becomes increasingly relevant, it has chosen to expand its purview to become more of an international friend of science. At the 174th annual meeting of the AAAS, we chose to reflect this new perspective.

As president of the AAAS, I was excited to make a global perspective on science and technology the focus of the meeting. I was inspired by Thomas Friedman's powerful book *The World Is Flat* (*1*), in which he suggests there is an increasingly level field for global commerce and competition. The increasingly global reach of *Science* was another impetus for the global theme. But most importantly, the key issues of science and technology today are not limited to the space encompassed by particular political borders. Provision of clean energy in the world is our most pressing problem and one we can only tackle together. Issues of health are international ones, especially in this era of jet travel. Poverty is a problem of some countries, but its effects spread throughout the world. Lack of sufficient clean water has become an international concern, affecting both rural populations and urban ones. And economics, the dismal but all-powerful driver of global wealth creation, highlights the interrelationship of all the world's people.

Science and the Coming Election

Before getting to our theme, I want to make a political aside focused on the United States. We have an imminent presidential election. Science and technology have played at best minor roles in the campaigns. A debate on science was proposed, and some 38,000 people, including scientists, engineers, business leaders, and concerned citizens, signed on to the proposal. The AAAS was a co-sponsor. The candidates' views of science, whether they want to hear its conclusions or want to hide from them, whether they want to have the thinking of our community represented in the White House or relegated to a distant office, whether they will support intensive investigation of alternative energy sources, whether they will liberate the biomedical community to fully investigate the power of stem cell technology, whether they will face the reality that abstinence is not the only way to protect people against HIV transmission, whether they will provide leadership or bury their heads in the sand when tough choices must be made, whether they will leave a better country than the one they inherit; all of these are critical questions with which they should be faced. They have commented on many of these issues in response to questions from the organization Science Debates 2008 (*2*) but refused to debate them.

A flatter world. Globalization of resources and technology is leveling the competitive playing fields between industrial and emerging-market countries.

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A key question they should have been asked, which is of particular interest to me, is whether they support an increase in funding for the National Institutes of Health. Barack Obama has indicated that he does, while John McCain has been less specific. It is criminal that at a time when the opportunities in biomedical research outstrip those at any other moment in history, there has been a 13% real decrease in the buying power of the health research budget between 2004 and the 2009 proposal. The current president has presided over this decimation of one of the jewels of American science, a jewel that has spawned the biotechnology industry, the one industry in which America is the unquestioned leader. How can we cede that lead to others by reducing support for the research that made it possible?

A Personal Perspective

Let me first share a bit about my history. As a Jewish boy growing up around New York in the post–World War II era, I lived with the parental expectation that I would become a doctor. In fact, I have always been interested in mammalian biology but, much to the chagrin of my father, although not my mother who was a scientist, I opted not to get an M.D. and have made my career as a Ph.D. Luckily, I received the Nobel Prize when I was still young, so both of my parents were alive to come to Stockholm and witness the event. And they forgave me for not getting an M.D.

My choice to go into research was not only an intellectual one; it was also a matter of having fun. For me, discovery was and remains, fun. As a high-school student, I spent a summer at the Jackson Laboratory in Maine, where senior investigators oversaw us in doing little experiments on the genetics of mice. I worked on three such experiments and although none was particularly important, I learned the pleasure of discovery and never forgot the lesson. In college, I spent a summer at Cold Spring Harbor and again had the thrill of being the first person to see a new piece of data from an experiment I had designed and performed. The joy of a new scientific result returns at each encounter, and it has been over 50 years since my first. That joy can come from someone else's result too, which is why I stopped doing experiments myself some 30

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years ago and have been directing others since then. The joy of discovery doesn't even have to come from work in my laboratory; reading a great paper in the literature is a thrill of which I never tire. So, I come to global science topics as a working scientist but a rank amateur when it comes to internationalism. However, I feel deeply that a scientist must go beyond his pleasure in his personal science and take some responsibility for the larger issues of the field.

And so I did a little globetrotting last year. Most memorably, I went to Rwanda and India. The contrast between these countries is striking. One is a tiny country, with 8 million closely packed people; the other is a sprawling nation with a billion people. One is still deeply underdeveloped but emerging sprightly from the unimaginable hell of genocide; the other is an established and vibrant democracy on an economic takeoff platform. What I saw in these two countries led me to believe that liberating the spirit of entrepreneurship is a key to economic development. People are the same around the world; free them and they start expressing their individual creativity. I saw the beginnings of that liberation in Rwanda (see sidebar). There is no doubt that in India, as in China, the liberation is in full swing.

Strengthening Science at Home and Abroad

In beginning a more general consideration of science in the world, I must admit to an apparent contradiction. We as scientists, engineers, and technologists generally believe that our professions know no borders. We read the literature to gain knowledge, independent of where the experiments were done. We travel to meetings all over the world, sharing our knowledge with anyone who wishes to listen. During the Cold War, we met with our Russian colleagues when we could, ignoring the headlines that made them out to be our enemies. The Pugwash movement, honored with the 1995 Nobel Peace Prize, was an embodiment of that world view (*3*). A good idea is a treasure, no matter what mind conceives it. The stronger world science is, the more ideas will bubble up, and the richer will be the brew of ideas and experiments that each of us can draw upon.

That is one side of the picture; the other is that we want our own countries to be strong. As an American, I will present this argument from our point of view, but it is equally applicable to any nationality. Our economic health, our security, our ability to live fulfilling and peaceful lives depend on America maintaining a strong base in science and technology. And America remains strong today. But we see that strength slipping and it worries us. The U.S. National Academy of Sciences embodied these worries in its report *Rising Above the Gathering Storm* (*4*). It is a highly nationalistic document, one that resonated with the science and education communities. It calls for programs to strengthen U.S. science so that we can compete in the newly global economy. By implication, strengthening foreign science would appear

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Cultivating science. For countries such as Rwanda, training in science and technology can help build economies and lift people out of poverty.

Challenges and Prospects of Advancing Science and Technology in Africa: The Case of Rwanda

Paul Kagame, President of the Republic of Rwanda

I was delighted to participate in the 2008 Annual Meeting of the American Association for the Advancement of Science and have the opportunity to highlight Africa's and Rwanda's challenges in using the power of science and technology to transform our societies. I believe that all nations must relentlessly build world-class knowledge institutions that create a robust stock of scientists and researchers, foster a dynamic private sector in which industries nurture innovative talents for prosperity creation, and establish professional public services managed by insightful policy-makers who actively promote science and education.

There can be no better inspiration than the United States. What we seek to achieve in Africa and in Rwanda is what is taken for granted in the U.S.: the continuous expansion of knowledge and innovation that lead to even greater prosperity through a triangular relationship between government, business, and academia. This multifaceted relationship is evident in the entire value chain of education from elementary school to tertiary level, and subsequently to the transfer of skills and knowledge in industry and workforce.

How, then, are we in Africa to create an environment that encourages the harnessing of science and education, which in turn permits a more rapid socioeconomic transformation? More specifically, what socioeconomic development choices have we made in Rwanda, and how are we progressing in utilizing education and science to achieve them?

The challenge on our continent is that each of the three players—government, business, and the university—has yet to consolidate their roles into an interdependent relationship that links demand and supply of scientific and technological innovations on a scale needed to transform our societies. This partly explains why Africa remains impoverished and trapped in the trading of raw

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to be against our interests. Therein lies the apparent contradiction.

Having wrestled with this contradiction in my own mind, I feel that I can resolve it. We need to look at the question from two points of view, each of which is equally valid but which give different perspectives. On the one hand, we want a peaceful world. The tension of economic competition helps to produce that because each country is concerned with its own development in a global context. Development promotes stability, optimism, independence, competitiveness, and a belief in the further value of progress. It counters the envy, pessimism, and hopelessness that generate terrorism. If science and technology are wellsprings of economic growth, the stronger the science internationally, the more peaceful will be the world. The other side of the coin is that we as Americans want our country to be particularly strong. We should, as we do, encourage that. We must recognize that we will not have a monopoly on innovation, but we will be able to keep our fair share. So the resolution of the contradiction is that we need to do both: keep ourselves strong and encourage others to develop. That will create a world where the tension of competition enriches us all.

The Institutional Perspective

Many American scientists are asked to advise countries abroad about how they can build great research institutions. This has been true for years; many of the Indian Institutes of Technology (IITs), which were started back in 1951, benefited from the advice of foreign scientists. IIT Kampur was advised in the 1960s by faculty from nine U.S. universities: I am proud to say that the California Institute of Technology (Caltech) and Massachusetts Institute of Technology (MIT) were among them. Remember that when you hear about the successes in India today and the many Indian scientists who populate U.S. academic institutions. For instance, InfoSys, the company that convinced Thomas Friedman that the world is flattening, was started by IIT Bombay graduates. Today, getting into an IIT is the dream of well-prepared Indian students, and the world competes for their graduates. When I visited InfoSys recently, I heard that they hire every IIT graduate they can convince to join them, no matter what their major. Then InfoSys trains them for its computer science–based needs. InfoSys competes with IBM and many other national and international companies for a too-small pool of talent. They keep setting up branches within India and now in the rest of the world to satisfy their voracious appetite for people. This success rests on the aid that India received from the world scientific community years ago.

So India, and China, and Saudi Arabia, and many other countries are now in the institution-building mode, and foreign scientists are again in demand as advisors. A former head of the National Academy of Sciences, for instance, is now a key advisor to Saudi Arabia in the building of the King Abdullah University of Science and Technology on the Red Sea—a bold attempt to build a modern institution with significant freedoms in a very repressive society. I too have been called upon for advice and have recently worked with the Indian government on their ambitious program to greatly extend their involvement in the life sciences. The American experience in building its institutions has been a remarkably effective process, and the American community of scientists is the embodiment of that experience—sharing it is both personally satisfying and an important contribution to world stability.

Five Rules for International Science Development

Every developing country has gotten the word that education is key to progress, and as they amass the resources to build, they are building. What I've seen in India and in China is a desire to build rapidly. These countries have the resources and now seem to want instant excellence. I find that very worrisome because building excellence takes time. So I have evolved a set of rules about development that I would like to share.

These rules have been inspired by my own personal history. I built one research institute, the Whitehead, and headed one specialized research university, Rockefeller, and one small comprehensive research university, Caltech. They have in common a characteristic that is central to my thinking: They are small and grow at most marginally. They run counter to the trend in academia to measure success by growth and to solve problems by growing away from them. But they have another common characteristic; they are, by anyone's measure, homes for excellence. And they have maintained excellence over decades, in one case for more than a century. Not all institutions in a society need aspire to this level of excellence, but the best ones are the bellwethers of academic life and thus key. The rules I have taken from these experiences are five:

1) In choosing people, demand excellence. Because excellent people are hard to find, this means hiring slowly and deliberately, never letting the desire to fill slots force poor decisions. Another corollary is that in a developing country, with a small base of developed talent, starting many institutions at once could be counterproductive.

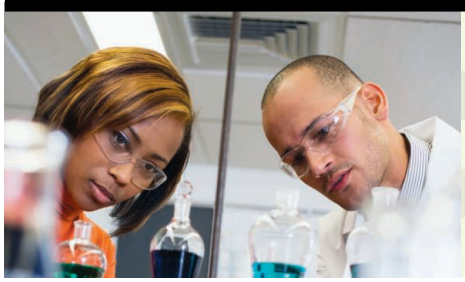
2) Concentrate resources. This means favoring one great small enterprise, perhaps at the expense of larger institutions. It is especially relevant today when the cost of doing pioneering research is so large.

3) Create small environments. One might counter my focus on smallness with the reasonable point that today research is increasingly interdisciplinary, giving an advantage to large, comprehensive institutions. However, by creating within large universities smaller, well-resourced centers, it is possible to get the values of both smallness and comprehensiveness. The Whitehead Institute, in its affiliation with MIT, is a good example. Caltech, amazingly, is both small and comprehensive, a notably hard mix to maintain.

4) Build institutions that unify teaching and research. In the United States, we know well that integrating teaching with research benefits both and ensures that there is always a pool of people trained to work at the forefront of their fields. But abroad, this unity is often lacking, imperiling continuity and short-changing students.

5) Ensure academic freedom. In the United States, this means maintaining tenure, a value that I rate more highly than do many others. Without academic freedom, there is a risk of

FIVE RULES FOR INTERNATIONAL SCIENCE DEVELOPMENT



1. Demand excellence
2. Concentrate resources
3. Create small environments
4. Maintain unity of teaching and research
5. Ensure academic freedom

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government dictation of the directions of science. Recently, the United States has seen how a government can attempt to suppress uncomfortable scientific knowledge when it dislikes the policy implications. Remember, in most countries of the world, governments control academic and research institutions. I will come back to this point.

Science Around the World

Science fits into different countries in different ways. In the United States and Europe, it is an established part of the culture and a generator of economic progress. In the United States especially, we have built commercial engines of innovation around our science and have a highly developed process for funding that innovation. In China, science is venerated and a rapidly growing enterprise, but it is still immature. In India, it is venerated and has an impressive history that is undergoing a renewal. In Africa, practicing science at almost any level is mainly a dream, but in certain countries, the dream is part of the plans for the future. Small countries aspire to having great science but are unable to produce a critical mass unless they import a significant fraction of their scientists. Israel, strikingly, shows that it is possible to keep the flow of scientists and engineers coming in spite of a small population.

> "American science, although largely government-funded, is actually a bottom-up entrepreneurial activity."
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> —DAVID BALTIMORE, CALIFORNIA INSTITUTE OF TECHNOLOGY

For all the differences of how science is practiced in different places and how it affects different countries, there is one constant. It is that basic science is funded by governments. It may be done in research institutes or in universities, it may be funded through institutions or directly to scientists, but it is a governmental activity because only governments have both the funds to afford it and the desire to support it. Poor countries therefore do little; rich countries can choose. In developing countries, there are limited funds and their investment becomes a matter of values. Private enterprise does a lot of applied science, and its research is often the proximate work that spurs innovation, but I believe that it is basic science that makes the leaps that produce the breakthrough concepts. The funding of basic science through investigator-initiated grants is America's secret weapon.

American science, although largely government-funded, is actually a bottom-up entrepreneurial activity. The institutions of science are largely not governmental—even the state universities are no longer mainly funded by the states. The practitioners are employees of the institutions but they get their funds through individual initiative. Tenure is a wonderful guarantee because it enables each scientist to run an individual program, to decide who to involve, who to collaborate with, how big an operation to run.

In the last few years, I have had occasion to visit many places around the world and have had at least a cursory look at their biological sciences activities. I'll begin with China and India. Together they represent almost 50% of the world's population, so what they do is of overriding importance. They are very different places.

China is a totalitarian country, which we should not forget. They may have a free market of commerce, but science is funded by the government, and the government, including the country's communist party, makes decisions. They decide where to build new universities, how much funding to distribute, where to send funds, and the priority that individual programs should have. The notion of a free market for doing science has not penetrated. There is a place for personal initiative, but the heavy hand of government dominates. They are involved in a huge expansion, but they score poorly on Baltimore's rules of scientific development.

India is a most interesting place. It has a great tradition of science, which was seeded under British rule and was carried forward by Nehru. However, it has fallen into mediocrity, and bright Indians have been traveling abroad, where opportunity is greater. The country is now committing itself to building strength in basic science. It is growing at an apparently sustainable 9% per year, spinning off huge resources for institutional development. India has a few pillars upon which to build: some fine existing institutions; a remarkable knowledge-based industry, mostly in the information technology area; an impressive generic pharmaceutical business; and a government commitment to building strength in education and research through new institutions. They understand quality and want it; whether they can stick to Baltimore's rules will be interesting to watch.

materials and natural resources, thereby transferring the more wealth-creating aspects of a value addition to developed countries. Innovative companies fail to emerge due to the low level of domestic processing. The government's role in promoting education and science both in industry and knowledge institutions remains feeble. Meanwhile, African universities have become almost irrelevant to our socioeconomic development, resulting in perpetual decline and brain drain as capable scientists and professionals leave the continent for better opportunities. The point here, however, is not to lament this condition, but rather to share with you what we are doing about it in Rwanda.

Let me first acknowledge that, in our country, we have neither a dynamic private sector that constitutes a strong demand factor for science and technology, nor strong knowledge institutions to meet such a demand. We do have, however, a developmental vision and a commitment to achieving it. Over the past 7 years, we have been laying the foundation for education and science to play their rightful roles in realizing our goals. As the strongest of the actors in development, Rwanda's public sector will continue to play a leading role for some time, while other pillars gain strength. Our modest progress in building this foundation may be summarized as follows:

First, we believe that "business as usual" in terms of depending on an economy based on raw material exports will merely entrap us into poverty. We must transcend this mindset and practice. With our objective of becoming a middle-income country by the year 2020, we reasoned that not only would we have to modernize our agriculture for value-added exports, but also to enter "nontraditional" economic niches, such as finance, high-end tourism, and the information and communication technologies (ICT) sectors.

Second, we concluded that Rwandans themselves constitute our principal national asset. We therefore had to refocus our education so that it can provide the people with the requisite skills and knowledge to become a viable multifaceted human capital. That is why we have consistently increased our education budget; about 25% of our national budget now goes to formal and nonformal education, constituting the largest single component of Rwanda's annual expenditure.

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At the same time, we shouldn't underestimate the challenge facing India. Today, only 57% of the 411 million school-age children in India ever enter school. They are experiencing a huge shortfall in trained engineers. For instance, although they graduate many computer scientists, they will need many times that over the next 3 years to fuel projected growth in their information technology–based industry. So they are outsourcing to Mexico, the Philippines, Thailand, and even Europe and the United States. Meanwhile, the rest of the world is still hungrily scanning India's talent pool for those we can entice to move West and feed our own appetite for effective workers in science and technology. What can be flatter than a world where a European company outsources a problem to India, which works it out in Asia, and then sees it applied in the United States?

To add a little color here, I want to tell you about an industry I found in India that I had no idea about. I was recently the guest of an Indian company called TnQ, which is partly housed in a modern building in Chennai. Inside this and their other buildings were 1000 people, mainly Ph.D.'s, sitting in front of computers, editing and preparing for both Web and print publication many of the journals that are "published" in the developed world. In particular, they publish many Elsevier journals, notably those of the Cell Press subsidiary. They printed out for me an article of mine that they had dealt with. I had no idea they were involved, because it can be difficult to know where in cyberspace your e-mails originate. With huge data pipes open to India, and English as their national language, Indians can play some surprising roles in the knowledge industry.

So, India and China are working hard to become competitive, but they both have a long way to go. Developing excellence is a slow, painstaking process. The developed world has a big head start and our job is an easier one, to maintain our established strength rather than building anew. Yes, the world is flatter, but it is still tipped in a Western and Northerly direction, with people sliding down the incline in our direction. Whether it is Indian computer scientists or Chinese biologists or Nigerian nurses, we offer better salaries, better opportunities, better educational environments for their children, and so we are still a huge draw. It will not last forever and we desperately need to provide the education for our citizens that will allow us to staff our own high-tech activities, but right now, as long as we don't scare people off, we are a great draw.

Gaining ground. India is working to build strength in education and basic research, yet struggles to retain its trained scientists and engineers.

Interestingly, while China and India are developing and are often cited as America's most serious competitors, our proximal competition actually comes from Europe. As an example, London is supplanting New York as the world's economic center. All you need do, as I did, is to spend some time in what Londoners call the City, their financial district. It is huge, full of glassy new buildings, and the plaques on the buildings tell the story: The world's commerce is represented here, even such quintessentially U.S. firms as Fidelity and T. Rowe Price. Parag Khanna of the *New York Times* recently analyzed the growth of Europe (*5*). He pointed out how effectively Europe is incorporating the vibrant border countries previously in the Soviet domain. Russia itself, as it shrinks in population and develops economic strength, could end up in the European sphere of influence, although its recent activities indicate that it may attempt to regain its own sphere of influence. Europe is even making inroads in South America. As the United States has allowed itself to become mesmerized by the terrorist threat from the Middle East, and allowed its relations to its historic neighbors and friends to diminish, it has left Europe to unite and become again a world power. Similarly, China is developing influence elsewhere in Asia and in Africa. We run a danger of returning to isolation. One might think of us as muscle-bound, but even our military is looking a bit tattered.

Yes, the world is flattening in the sense that you can do today in Bangalore what you could only do in the developed world 10 years ago. But there are huge differences between India and China and the United States in terms of infrastructure, education, culture, and capital, and these will not go away soon. We in the United States have a platform on which to build our future and secure a strong position in the global world coming in the next decades. We must be conscious of the long-term threat of competition that we face and prepare ourselves to compete. Our military will not be our ticket, and one could argue that it has seduced us into a misapplication of our remarkable resources. When America gained the mantle of being a world superpower, it took on responsibility for the world. We need to spend more time thinking about our responsibility to ourselves, about the need to rebuild our internal infrastructure, our educational system, our scientific prowess. Those will be the elements of the future. The AAAS can play a role, helping to guide the country back on a path that can at once provide internal strength, interna-

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Controlled growth. Science is a growing enterprise in China, but government funds and decisions rather than personal initiatives dominate its practice.

CREDIT: JUPITER IMAGES

tional morality, and a concern for worldwide development. It will be the tension of economic competition, not the threat of a military strike, that will keep the world stable and peaceful in the future, and we need to focus on the leadership role we can play.

Science in Less Developed Countries

Thus far, our major focus in discussing science has been its role in driving economic development in the developed and developing world. But how about the truly needy countries, the ones where development has yet to make much of a dent? Nongovernmental organizations (NGOs) have generally felt that the needs in these countries are so pressing and so basic that aid should concentrate on their immediate needs, not on high-tech science. But a number of thinkers disagree. At the 2007 AAAS annual meeting, Mohamed Hassan, executive director of the Academy of Sciences for the Developing World, spoke of the role that science, technology, and innovation can play in the development of Africa. I agree with him that the innovation enabled by strong science and technology can catalyze development and that investments there will pay off in the future. He also pointed out that countries that are now more developed and growing (like Brazil, China, India, Malaysia, South Africa, Turkey, and others) are investing in science and technology, creating a multipolar world of science. These are countries with a strong base, positive growth rates, and increasingly replete government coffers. They can afford to build research facilities. But they all had traditions of research and education as well as institutions to build upon. Sometimes these date from their colonial period. The African countries have much less, and even when their colonial masters built universities, periods of ruinous dictatorship and wars left the institutions in a shambles. Many are now trying to rebuild.

There needs to be an emphasis on institution-strengthening in Africa. Africa needs research, but perhaps a greater need is more trained people. People trained in science and technology can contribute in many ways to economic development. And Baltimore's rules apply. Thus, the institutions that are built should combine teaching and research. It is important to start small, concentrating available resources and talent until such time as there are sufficient trained personnel for further expansion. International institutions within Africa would be best, but it may be too much to wish that African countries

Third, we made primary-school education free of tuition fees in 2004, and this policy was extended to the first 3 years of secondary education as of last year. The goal is to enable all Rwandan youth to access basic education. Ninety-six percent of primary-school–age children in Rwanda now have free access to education, a statistic that we are determined to improve, in addition to working harder to improve the quality of our education. It is in this context that the teaching of mathematics and sciences at all levels of our educational system now constitutes a national priority.

Fourth, we have concurrently established and strengthened tertiary education to provide knowledge and skills in areas critical for realizing our socioeconomic development objectives. Institutions for this sector include the Kigali Health Institute, the Kigali Institute of Education, and the Institute of Agriculture and Animal Husbandry, among others. The National University of Rwanda also continues to undergo capacity development, especially in the teaching of science subjects.

Lastly and more directly related to the promotion of science, we have increased our expenditure for this field. Today, 1.6% of our gross domestic product supports this effort. Our target is to increase this to 5% by the year 2012. We have also established a ministry in charge of science and technology, which, in turn, has elaborated a strategy to ensure the achievement of the above efforts.

What are the results so far?

More and more Rwandans are literate, and these trained citizens are contributing to the rise of a more dynamic and nontraditional private sector that is increasingly playing a more substantive role in our economy. For example, tourism has already surpassed tea as one of Rwanda's leading economic subsectors. With more focus on strengthening the different clusters of tourism, we believe this sector will soon become a vital export niche.

But it is the ICT sector, led by mobile telephone technologies, that confirms our belief in pursuing nontraditional economic development pathways. Consider, for instance, the fact that the subscribers of the leading mobile phone company numbered about 320,000 in 2006. This number almost doubled last year to about 613,000, and the number of subscribers is projected to increase to one million by the end of 2008. This company, which is a joint venture

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share resources to build the best possible universities. It will take significant and sustained foreign aid and assistance from universities of the developed world to build such institutions, but the payoff could be immense.

Building science and technology capability is a long-term effort. Only in the context of political stability will it work. The NGOs of the world have learned this lesson and are putting an increasing fraction of their aid into countries that are stable, reasonably honest, and intelligently led. This is also where the long-term bets should be made, with the understanding that present stability may not be a guarantee of future stability.

Africa is a patchwork of countries in very different circumstances. Some very small countries provide great opportunity, like Paul Kagame's Rwanda. When I visited there earlier this year, I was impressed by the commitment to science and technology as a generator of economic growth even in this very poor country, so recently caught up in its horrific spasm of genocide. They are now building institutions able to train nurses and other medical personnel so that they have the people to deal with AIDS and other medical needs. They are also increasing their university education to train doctors, engineers, and scientists. Although it may take some years for this country to achieve political maturity amidst lingering ethnic tensions, the honest and meritocratic government of President Kagame, supported by investments from abroad, is encouraging. Theirs is a leading-edge experiment, testing the role that science and technology can play in African development.

But huge challenges remain in Africa, where legacies of tribal conflict often undermine attempts to develop institutions. Congo is an example. It is one of the largest countries of Africa but perennially dealing with internal strife. South Africa is by far the leading country of Africa and has some impressive universities and even does world-class science. But there, the leadership has believed in myths about AIDS, not realities, sadly leaving the country to fight this scourge without high-level support. And the toll has been terrible.

A grand challenge. Combating AIDS and other diseases that disproportionately affect the world's poor demands the best scientific resources available.

CREDIT: GIDEON MENDEL/CORBIS

The AIDS Vaccine Grand Challenge

Addressing the most pressing scientific and medical challenges facing less developed countries is not something that these nations can do alone. Halting the scourge of AIDS in Africa is a prime example. There is still no AIDS vaccine and no hopeful candidate vaccine. HIV, the cause of AIDS, has evolved to be virtually impossible to attack by antibody, and without antibody sensitivity it is pretty well uncontrollable by the immune system. This means that to control HIV immunologically, the scientific community has to beat out nature—to do something that nature, with its advantage of 4 billion years of evolution, has not been able do.

The vaccine community has tried its best. It initially made an attempt to control the virus through antibodies but found that the virus was quite solidly protected against that mode of attack. It then switched to trying the other arm of immune protection, the cellular immune system. That has never been mobilized to protect against a virus because it was not thought to be powerful enough. Sure enough, in a full-scale clinical trial the first such candidate vaccine gave no protection. The community is still trying this route of attack because it is one of the few natural hopes we have.

None of this work could have been done anywhere but in the most technologically advanced countries. It involves the most sophisticated concepts and techniques of modern science. But even so, it has not worked. Although our lack of success of may be understandable, it is not acceptable. Our only hope may lie in inventing new ways of providing antiviral protection. Four years ago, I proposed such an endeavor to the Grand Challenges in Global Health Initiative (*6*) of the Bill and Melinda Gates Foundation. Without getting too technical, the strategy was to combine gene therapy, immunologic therapy, and stem cell therapy to stimulate an immunological attack on HIV. Now in our third year of this challenge, I can report that it is as difficult as we imagined. We are still in the stage of developing the tools, the systems, and the materials we need to even attempt a serious test of the idea. But one thing is for sure: Only in the most highly developed laboratories with the best-trained people would this endeavor even be conceivable.

An AIDS vaccine, a tuberculosis vaccine, and a malaria vaccine are all grand challenges. We need the very best laboratories to undertake them. And we need visionary funders like the Gates family to make these efforts possible. Then, of course, if there is even a glimmer of hope, the materials need to be tested in a partnership between the counties that suffer from the diseases and those that have developed candidate vaccines. And we must be certain that the developed materials are affordable by those who most need them.

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An Admission and a Wish

In concluding this essay, I want to say something very difficult. I don't know if I speak for just myself or for many readers. Since 2001, I have lived a life of denial. I have denied responsibility for the actions of America. I have denied that President Bush speaks for and represents my country. I have held my breath, awaiting new inhabitants of Washington who will again be the moral, thoughtful, balanced people who are the true Americans.

But do I have that right of denial, the right to pretend that American actions are not about me? Mustn't I take some responsibility because our government is a creature of the democracy we cherish? Forced by the president, the Congress this year accepted a budget that does not meet the needs of America but there was no uprising by the people. We accepted the right of the president to starve our scientific enterprise: We can only complain, not change the result. Denial is wonderful. We tell ourselves that we travel as people, not as representatives of our country, when in fact we should travel with our head held low, doing penance for the horrors inflicted by our country at Abu Ghraib, at Guantanamo Bay, and in secret jails in eastern Europe. I am old enough to remember going to Europe in 1960 when we were so proud to be Americans, when we could still bask in the reflected glory of the gift of victory we gave the world in World War II. What a long time it has been.

But I have a hope for the future. I hope that when Jim McCarthy takes the reins as the next AAAS president, he will be able to bring a message of optimism. Optimism that our country is prepared to once again act morally, no matter what the provocation; optimism that we will face up to our responsibility to posterity to seriously deal with global warming; optimism that we will reinvigorate our investment in our future, rising to meet the gathering storm; optimism that the tide of religion-based anti-intellectualism that has gripped our nation is being turned.

Then we can reassert our belief in America once again. We can move from denial to pride. We can hold our heads up high as we travel the world, knowing that our fine democracy has once again produced leadership worthy of our great country.

Is this too much to ask, I wonder.

References and Notes

1. T. L. Friedman, *The World Is Flat* (Farrar, Straus & Giroux, New York, 2005).
2. Science Debate 2008 worked with Scientists and Engineers for America, the AAAS, the National Academies, the Council on Competitiveness, and other organizations to craft the top 14 questions the candidates should answer. Their answers can be found at www.sciencedebate2008.com/www/index.php?id=42.
3. The 1995 Nobel Peace Prize was jointly awarded to Joseph Rotblat and to the Pugwash Conferences on Science and World Affairs, for their efforts to diminish the part played by nuclear arms in international politics and, in the longer run, to eliminate such arms. Today, the Pugwash mission is to bring scientific insight and reason to bear on threats to human security arising from science and technology, and particularly the threats to humanity posed by nuclear and other weapons of mass destruction (www.pugwash.org/).
4. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academy Press, Washington, DC, 2007).
5. P. Khanna, "Waiving goodbye to hegemony," *New York Times Magazine* (27 January 2008).
6. The Grand Challenges in Global Health Initiative aims to address the health problems that disproportionately affect the world's poorest people and was built on the assumption that with greater encouragement and funding, contemporary science and technology can remove some of the obstacles to more rapid progress (www.gcgh.org/Pages/default.aspx).

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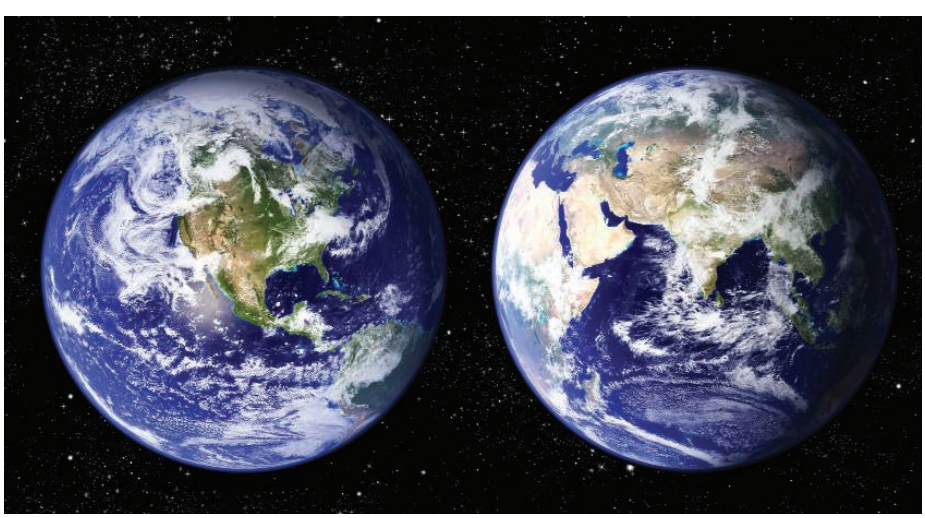

A global perspective. Innovation fueled by a strong science and technology base is as crucial for developing countries as it is for the rest of the world.

between Rwandans and a South African firm, has become the largest taxpayer in our country. And the ICT sector in general has surpassed all other fields to become the leading wealth creator in our country.

The multiplier effects on the rest of Rwanda's private sector have been significant, especially in service industries including advertising agencies, printing companies, public relations, radio stations, and newspaper businesses. We have also recently privatized the national telephone company with the goal of transferring business operations from government to the private sector and to promote innovative foreign investments. In terms of ICT infrastructure expansion, I should note that our global system for mobile communications (GSM) network now covers 82% of Rwanda, while a fiber optic backbone rings our capital city, Kigali. The overall objective is to link all Rwandan towns and districts by the year 2009, which will greatly improve service delivery to rural areas, especially in health and education.

I would like to conclude on the following note. Advancing science in the developing world is vital for creating an engaged, prosperous, healthier, and peaceful world. Africa is no exception, and we Africans must lead the way promoting education, science, and technology to urgently enhance our prospects for improving lives. It is evident that social, economic, and political development processes in Africa remain uneven with occasional setbacks, but we must keep the steady course of using the powerful tools of science and technology.

We have made a good start in Rwanda, but challenges clearly remain. Among them is the human factor. Because we have started from a particularly low base, enabling our universities and tertiary sector to provide capable professionals to power our development process is no easy task. I am certain that AAAS has a role to play in this effort. I have requested the Rwandan minister in charge of science and technology to work with AAAS closely and tap into the American network of scientists and educators to improve our science and teaching institutions. We should strive to make this relationship a two-way endeavor. For example, Rwanda's rich biodiversity could provide American scientists with considerable research opportunities. I look forward to our continued partnership.

Comments delivered at the 2008 AAAS Annual Meeting.